MASTER OF SCIENCE
IN
ENGINEERING ACOUSTICS

DENOISING OF OCEAN ACOUSTIC SIGNALS
USING WAVELET-BASED TECHNIQUES

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This thesis investigates the use of wavelets, wavelet packets, and cosine packet signal decompositions for the removal of noise from underwater acoustic signals. Several wavelet-based denoising techniques are presented and their performances compared. Results from the comparisons are used to develop a wavelet-based denoising algorithm suitable for a wide variety of underwater acoustic transients. Performances of the denoising algorithm are compared to those of a short-time Wiener filter implementation and demonstrate that wavelet-based methods are a viable tool for the denoising of acoustic data.

INVESTIGATION OF A CONSTRICTED ANNULAR ACOUSTIC RESONATOR

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One topic of current interest in thermoacoustic research is an annular prime mover (LIN et al., *Journal of Acoustical Society of America*, 100, 2846, 1996). The starting point for this research is an investigation of a constricted annular resonator. A literature search of the field resulted in surprisingly few references. The results of analytic, numerical, and experimental investigations are presented. Introducing a constriction into an annular resonator splits each longitudinal duct mode into two modes, one of a higher frequency with a pressure antinode at the constriction and one at a lower frequency with a velocity antinode near the constriction. The lower mode is more sensitive to changes in the length and porosity of the constriction than the higher mode. Overall agreement between measured and predicted mode shapes and resonance frequencies is very good. It was found that it is necessary to include end corrections at the constriction to get accurate agreement between measured and predicted results.

MASTER OF SCIENCE IN ENGINEERING ACOUSTICS

INTERACTIVE TOOLS FOR SOUND SIGNAL ANALYSIS/SYNTHESIS BASED ON A SINUSOIDAL REPRESENTATION

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This thesis develops a series of programs that implement the sinusoidal representation model for speech and sound waveform analysis and synthesis. This sinusoidal representation model can also be used for a variety of sound signal transformations such as time-scale modification and frequency scaling. The above sound analysis/synthesis sinusoidal representations and transformations were developed as two interactive tools with Graphical User Interface (GUI) using MATLAB. In addition, an interactive tool for signal frequency component editing based on the sinusoidal model is also presented in this thesis.

VARIATIONS ON AUTOCORRELATION MATCHING AND THE SIFT LOCALIZATION ALGORITHM

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As part of the existing acoustic transient localization program, a feasibility study was performed to apply existing algorithms to signals at higher carrier frequencies. The coherent matching, autocorrelation matching and SIFT algorithms are time domain Matched Field Processing algorithms based on arrival structures for single hydrophone applications. In previous studies, these algorithms were employed only at lower frequencies using ray propagation models to create the replicas with varying success. This study is meant to investigate the performance of the algorithms at higher frequencies, using both the University of Miami Parabolic Equation (UMPE) Model and the Hamiltonian Raytracing Program for the Ocean (HARPO), to give insight into the previously unexplained inconsistent behavior of the algorithms at low frequencies, to improve and optimize existing algorithms, to point out improvements to existing eigenray extraction programs, and to suggest additional signal processing on the signal. Simulations are performed and synthetic signals are generated using both the HARPO and UMPE models. The arrival structures are investigated and the relation between features in the arrival structures for matching and the physical parameters are identified. Some insight into the performance of the SIFT algorithm is gained which relates matching and physical parameters. Simulations lead to improvements and optimization of the algorithms and give insight into the performance at higher frequencies.

COMPUTER PROGRAMS SUPPORTING INSTRUCTION IN ACOUSTICS

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Traditionally, the study of mechanical vibration and sound wave propagation has been presented through textbooks, classroom discussion and laboratory experiments. However, in today's academic environment, students have access to high performance computing facilities which can greatly augment the learning process. This thesis provides computer algorithms for examining selected topics drawn from the text, *Fundamentals of Acoustics*, Third Edition, John Wiley & Sons, Inc., by Kinsler, Frey, Coppens, and Sanders, (KFCS). Emphasis is on using the modeling and simulation capability of the programming language, MATLAB, to illustrate and analyze complex physical principles which may seem obscure on the printed page yet are challenging or inconvenient to duplicate in the laboratory. This is not a passive recitation of acoustic

phenomena, but complements KFCS with interactive student participation. The usefulness of these programs and any weaknesses in format or content needs to be tested in the classroom.

HARDWARE MODIFICATIONS AND INSTRUMENTATION OF THE THERMOACOUSTICALLY DRIVEN THERMOACOUSTIC REFRIGERATOR

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This thesis describes hardware modifications, instrumentation, and measurements taken with a heat driven refrigerator apparatus. Basic engine operation requires a heat source for the thermoacoustic driver which produces a high amplitude acoustic standing wave in a resonant vessel. Acoustic energy is extracted from the wave by the thermoacoustic refrigerator, located in the same vessel, which produces the cooling power. The engine has no moving parts.

The measurements characterize the performance of the driver half of the engine in terms of amplitude and heat input with respect to changes of the "stack" component, resonator tuning, and gas type. Amplitudes as high as 9.5% (peak/mean pressure) were achieved, and control of onset and amplitude were generally excellent although some amplitude instabilities were observed. Preliminary refrigeration measurements were also made, with substantial amounts of cooling power produced.

EXPERIMENTAL AND NUMERICAL INVESTIGATIONS OF THE GAUSSIAN SUPPRESSION OF SOUND BY SOUND

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In this work we report on experimental and numerical investigations of the attenuation of a small-amplitude signal due to its interaction with high intensity, band limited sound whose spectrum consists of up to four discrete peaks. We probe the "thermodynamic limit" for different configurations of the spectral components. In particular the attenuation of the signal is investigated for both equally and unequally spaced spectral components, as well as different phase relations among them. The possibility of collective modes is also explored by measurements of the phase change in the signal downstream due to the presence of discrete noise.

ACOUSTIC SOURCE AND DATA ACQUISITION SYSTEM FOR A HELICOPTER ROTOR BLADE-VORTEX INTERACTION (BVI) NOISE REDUCTION EXPERIMENT

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One of the most objectional noises produced by a helicopter is due to interaction of a rotor blade with a previously shed vortex. Various methods have been proposed to reduce this blade-vortex interaction (BVI) noise; this investigation is concerned with BVI noise reduction by rotor blade tip design modifications. Potentially much can be learned regarding the prospect for success of a candidate rotor blade design at greatly reduced time and money by performing acoustic scattering measurements in an anechoic chamber. It is proposed that a rotor blade which scatters acoustic waves less could be expected to produce less BVI noise. This thesis describes the development of the acoustic source and computer controlled data acquisition system for such a scattering experiment.

EVOLUTION OF THE TEMPERATURE PROFILE IN A SIMPLE THERMOACOUSTIC STACK

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The purpose of this thesis is to provide data on the evolution of the temperature profile in a simple thermoacoustic stack. These measurements are made to support the development of nonlinear time-dependent models of thermoacoustics. An acoustic resonator and driver is used with a five-plate stainless steel stack. The center plate of the stack is instrumented with nine thermocouples, one in the midpoint and four near each end of the plate. The edge thermocouples are located within an acoustic displacement amplitude of one another at high amplitude drive conditions.

Temperature evolution data is recorded for both argon and helium gases at several mean pressures and several drive ratios with the stack located between a pressure node and antinode. This data showed a deviation from linear theory at drive ratios above 1.5%. A crossover of gradient magnitudes is evident during gradient formation with edge thermocouple pairs initially forming larger gradients but dropping in magnitude to less than those of the inner thermocouple pairs after 25-56 seconds. As the gradients approached steady state conditions, they split into two groups of gradient pairs that appeared independent of displacement amplitude. Measurements are also made with the stack positioned in the vicinity of a pressure node and a pressure anti node. This data will be used for future study.